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REPORT NO. 683.1A

"IRON BIRD" MODEL
FOR
AGILE PROGRAM

June 1983

Approved for Public Release:
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Anamet Laboratories, Inc.

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Aerospace Structures
Information and Analysis Center

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Operated for the Flight Dynamics Laboratory by Anamet Laboratories, Inc.

PREFACE

This report was prepared by William H. Kuntz of Delta Dynamics, Inc. for the Flight Dynamics Laboratory (FD), Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. The work was performed within the scope of the Aerospace Structures Information and Analysis, which is operated for the Flight Dynamics Laboratory by Anamet Laboratories, Inc. under Contract No. F33615-81-C-3201. As Problem No. 404, the work was accomplished under Anamet Purchase Order No. 3411. Mr. Gordon R. Negaard, was the project monitor for Anamet Laboratories, Inc.

"IRON BIRD" MODEL

FOR

LABORATORY INVESTIGATION OF
AIRCRAFT GROUND INDUCED LOADS EXCITATION

AGILE PROGRAM

FEASIBILITY STUDY

CONTENTS

MAY 1983

DELTA DYNAMICS, INC.

DAYTON, OHIO

SUBJECT:

FEASIBILITY STUDY OF FULL SCALE DYNAMIC SIMULATION OF AIRCRAFT STRUCTURES FOR THE AGILE PROGRAM

PURPOSE:

To generate practical designs and provide cost estimates for the F-4, F-15, and F-16 simulations (IRON BIRDS) in response to a request from FIBR.

DISCUSSION:

1) A number of test programs have been conducted using instrumented aircraft operating over runways on which bumps due to runway repair have been simulated. The tests are reported to be expensive because of the operational costs of using actual aircraft and any structural damage resulting from the tests adds to the cost. In addition, the data are often non-repeatable because of the large number of variables involved. Correlation with theory is therefore difficult.

2) The idea of using laboratory tests has been proposed as an alternative under the name "Agile" i.e. "Aircraft Ground Induced Load Excitation". In this project, excitation will be applied to the test aircraft by means of hydraulic shakers located under each of the landing gear. The objective is to partially simulate rough field operation under a controlled environment to obtain consistent data at relatively low cost. These test data will include direct measurements of structural accelerations which will be correlated with theory. It is expected that this correlation will assist in the development of improved math models for dynamic load prediction and for the evaluation of new landing gear concepts which may be proposed to reduce the loads caused by rough runway operation.

3) If the models include simulations of important non-linear effects, the testing of full scale dynamic models in lieu of actual aircraft for Agile will provide the correct information on the loads, shears, moments and strain energies. However, the stresses will be correct only for the actual aircraft components used on the model such as the landing gear, stores and pylons. Calculations or tests using the loads obtained from the dynamic model test data will have to be conducted to determine the stresses in other parts of the aircraft such as the wing and fuselage structures and the actual fittings used on the aircraft to attach the landing gear and pylons. Nevetheless, the use of models in lieu of actual aircraft has been considered for the following reasons:

a) The costs involved when an actual aircraft is used for the tests are believed to be much greater than the costs of a model.

b) Limitations on the test environment may be required to avoid structural damage to an actual airplane. The model can be designed to withstand higher loads and can be repaired at lower costs.

c) The cost of modifying the model to accept a new landing gear design is expected to be much less than the cost of modifying an actual aircraft.

d) The use of a model may permit the simulation of aircraft which have not been built as well as the simulation of aircraft too large to be tested with available shakers. However a reduction in scale will cause a corresponding reduction in the deflections due to gravity, so that methods of compensating for these reduced deflections will be needed.

4) The feasibility of the model approach depends primarily on the cost of building the model. Mimimum costs may be achieved by selecting design features that make use of standard stock sizes, by shearing or torch cutting the outline of parts which will be assembled by welding, by eliminating the need for expensive tooling, jigs and fixtures and by compromises in the dynamic simulation.

5) The compromises in dynamic simulation proposed for Agile are as follows:

a) The wing will be designed for the bending and torsional stiffnesses and the weight distribution. The centers of gravity and pitch moments of inertia will not be precisely scaled since the torsional frequency of the wing without stores is expected be too high to be a critical dynamic loading frequency for Agile. In addition, the masses of the stores are expected to contribute the major portions of the effective masses of the wing vibration modes excited during Agile testing.

b) The tail will not be scaled since the natural frequencies of the tail modes are expected to be too high to produce significant dynamic loads in the Agile environment.

c) The fuselage will be designed for the correct mass distibution along the longitudinal axis, the correct vertical bending stiffness between the main and nose gear and the approximate vertical bending stiffnesses elsewhere. The use of a round tube, as discussed in sect. 7), will result in reasonable values for the lateral bending and torsional stiffnesses.

6) The design approach used for the wing was as follows :

a) About 75% of the allowable weight per inch of span is used to calculate the cross-section areas of the top and bottom plates depending on the material selected. Since aluminum is about 1/3 the density of steel, an aluminum alloy wing will have three times the cross-section area of a steel wing.

b) The vertical spacing between the top and bottom plates is determined from the vertical bending stiffness or "EI" of the wing. Since "E" for steel is three times "E" for aluminum, the moment of inertia for steel will be 1/3 that for aluminum. However the mean spacing between the top and bottom plates will be the same for both materials, since the area of steel is one third of the area for aluminum as pointed out in a) above.

c) The widths of the top and bottom plates are determined from the moments of inertia in fore and aft bending.

d) The fore and aft spacing of the main spars is computed from the torsional stiffness. Intermediate spars if used are spaced at about 30 times the thickness of the top and bottom plates to prevent buckling.

e) The strength depends on the material selected since EI is fixed and the bending stress is approximately equal to the bending moment divided by the product of the mean plate spacing and the cross-section area of one of the plates. For example, if steel is used, the stress will be about three times the stress in aluminum since as pointed out above the mean plate spacing will be about the same in both cases and the area of steel is 1/3 the area of the aluminum.

f) A special weldable aluminum alloy either 7005 or 7039 was selected for the wing since the ultimate tensile stress has been reported to be in the neighborhood of 60,000 p.s.i. and no heat treatment is required after welding. To obtain equal strength with steel, a 180,000 p.s.i. allowable would be needed and three times as many intermediate spars would be used since the steel plates will have about one third the thicknesses of the aluminum plates. The limited information available to Delta Dynamics at this time indicates that the only disadvantage to the above alloys is that they must be purchased directly from the manufacturer in 7,000 pound lots for each thickness required for the model.

7) The design approach used for the fuselage was as follows:

a) A tubular or solid cylindrical structure providing approximately the correct weight per inch of length and "EI" in

vertical bending was sought because built up rectangular or square structural designs would require extensive welding and the addition of weights, if required, would increase the costs.

b) The material selection was based on stress considerations as well as the costs of fabrication. The stress due to a bending moment M is given by MR/I where "R" is the radius of the tube or cylindrical bar. Since "I" for the aluminum fuselage is three times "I" for the steel fuselage and "I" is proportional to the fourth power of the radius for a solid bar, the stress in aluminum will be about 44% of the stress in steel. For the heavy walled tubing proposed in this simulation, the reduction of stress using an aluminum alloy tube will be slightly larger. The stress in aluminum will however drop to one-third of the stress in steel, for designs in which the mean radii are the same for the aluminum and steel fuselages.

c) Despite the higher stress levels, steel tubing was selected over aluminum because of the lower cost per pound, the ease in welding attachment fittings and the large ratio of non structural to structural weight which exists in the fuselages of the aircraft selected for simulation. In addition steel tubing in the sizes required to meet the design criteria in a) above appears to be readily available while aluminum tubing or bar stock would have to be ordered special.

d) Stress analyses conducted for the fuselage simulated by a steel tube with a heavy wall show margins that appear to be adequate for Agile because the outside radius of the model fuselage is less than one third of the fuselage radius. In cases where a large reduction in radius is not practical because of weight limitations, an aluminum alloy fuselage might have to be used to withstand the stresses imposed by the AGILE environment.

e) Shear deflections on the model fuselage will be substantially less than on the airplane because the reduction in radius requires an increase in cross sectional area to obtain the same stiffness and it may be necessary to reduce "EI" on the model somewhat to compensate. However, it appears likely that shear effects will not be substantial for the modes being simulated for Agile.

8) The attachment of landing gear and stores could substantially increase the model costs if the complicated fittings used on certain aircraft are employed. The solutions proposed are as follows:

a) Steel fittings will be bolted to the wing carry-through structure to fasten the main gear and to the fuselage to fasten the nose gear. No structure will be added for landing gear retraction.

b) The pylons will be bolted to blocks welded to the wing structure and actual pylons and stores will be used if available. Store ejection mechanisms will not be simulated.

c) In the event that actual pylons require complicated fittings, simulated pylons that can be bolted directly to blocks welded to the wing structure are proposed.

9) The costs of fabricating the models cannot be predicted with great confidence because no simple procedure could be found for accurately computing the hours required for: a) handling the component parts of the model structure, b) welding including setups, and c) assembling the model with proper allowance for assembly problems. The substantial expenditures that seem to be required to develop precise cost estimating procedures for the Iron Bird project do not appear to be justified since the costs of the proposed designs are expected to be close to minimum. An approximate cost estimate was made using the following procedure:

a) The costs of the materials were obtained from the suppliers.

b) The fabrication costs were estimated for each step in the fabrication process.

c) The assembly costs were estimated with allowances for assembly problems.

10) Details concerning the cost analysis are contained in Appendix III. Major cost items are as follows:

a) The costs of the wing material could be about $75,000 because the minimum order for the special alloy used is about $15,000 for each size and five different sizes will be required. The weight of the minimum order is 7,000 pounds so 35,000 pounds will be on hand while 4100 pounds is about the maximum required for any one of the three Iron Birds. Two possibilities exist for reducing the costs of the wing material: 1) etch or machine the special aluminum alloy to reduce the number of sizes required and, 2) replace the special alloy with 6061 and heat-treat the wing. Machining seems preferred at this time even though no precise cost figures could be obtained. An estimate for etching the F-16 wing covers was $2800 per cover compared to $1200 for machining. The use of 6061 appears impractical because the heat-treating of large structures which may require modification and frequent repair would be expensive and time consuming.

b) The steel tubing will run about $0.75 per pound, so $25,000 should cover steel costs making some allowance for scrap.

c) We have received an estimate from T&R Welding of $13,055 plus material costs for fabricating an Iron Bird for the F-16. This quotation does not include the installations of the landing gear and stores, the fabrication of any special fittings required or the costs of any modifications needed for Agile applications. Despite the above estimate, our experience with the fabrication of experimental items indicates that substantial overruns can occur because of engineering errors, unforeseen technical difficulties, shop errors, non productive labor hours and the difficulties of accurately predicting the costs mentioned above. On the basis of our experience, we currently estimate that the fabrication cost could be approximately $75,000 (labor only) for the first Iron Bird.

d) In view of the above, the total cost of the first Iron Bird could be $175,000. However, the uncertainties will result in such large contingencies in a fixed price quotation that the project, if approved, should probably be carried out thru a cost type of contract with tight cost controls.

e) Substantial reductions in the costs of the additional models are expected for the following reasons: 1) The experience obtained from the first Iron Bird is expected to result in substantially lower fabrication costs, 2) The design includes a common center fuselage and carry through structure for all three aircraft and 3) The cost estimate is based on the assumption that 35,000 pounds of the special alloy will be purchased in the sizes selected for the wing structures even though there is some indication that machining can reduce the amount of material that must be purchased.

11) To check out the feasibility of the F-16 design, a one-eighth scale model of the F-16 Iron Bird was fabricated and tested. The tests indicated that a substantial reduction in stiffness was needed at the wing root joint and weights had to be added to the fuselage to increase the moment of inertia in roll. The low stiffness at the wing root attachment could result from the bolted joint used on the airplane and bending of the fuselage bulkheads. The rolling moment of inertia was low because, as mentioned above, the radius of the steel tubing was only about a third of fuselage radius and the tails were not simulated. Acceptable dynamic simulation of the F-16 for AGILE was acheived with the above changes installed on the model. Additional information regarding this model is contained in appendices I and II.

CONCLUSIONS:

1) The fabrication of full scale dynamic simulations (IRON BIRDS) of the F-4, F-15, and F-16 for the Agile test program appears to be practical.

2) More accurate cost estimates can be provided by Delta Dynamics after the first Iron Bird has been fabricated.

3) The cost estimates that were made are lower than Delta Dynamics would have expected for the sizes and weights of the Iron Birds considered in this report.

4) The costs will increase if more accurate dynamic simulations than those proposed in this report are required.

RECOMMENDATIONS:

1) Fabrication of Iron Birds of the F-4, F-15, or other aircraft for AGILE should not be attempted without test data from reduced scale models.

2) The special aluminum alloy selected for the wing should be thoroughly investigated to uncover any disadvantages which might possibly explain why the material is not available from our regular suppliers.

3) A review of aircraft structural damage caused by rough runway operation should be conducted to determine whether or not the proposed compromises contained in this report are permissible in the dynamic simulation of Iron Birds for AGILE.

4) If feasible, important non-linear effects should be simulated in the IRON BIRDS.

Submitted By

W.H. Kuntz and

L.S. Wasserman

F-16 - FULL SCALE

MODEL DESIGN

SIMULATION:

Under the AGILE program, shakers will be used to apply programmed motions to the landing gear. The airplane dynamic response is related to particular frequencies and modes. The primary model design objective is to create a physical model that posesses the effective mass and stiffness properties necessary to reproduce the dynamics of the airplane that control these frequencies and modes. The design data is taken from the analytical math model prepared for modal calculations. Neither model attempts to represent the details of the airplane structure. The effect of joints and fittings may only be defined by equivalent stiffness or by influence coefficients. The design of the physical model is done in a way that the major load paths are approximated. When tests have been performed on the physical model and correlation with the airplane and the analytical model is demonstrated, then confidence is established in the use of the analytical model to predict dynamic response loads.

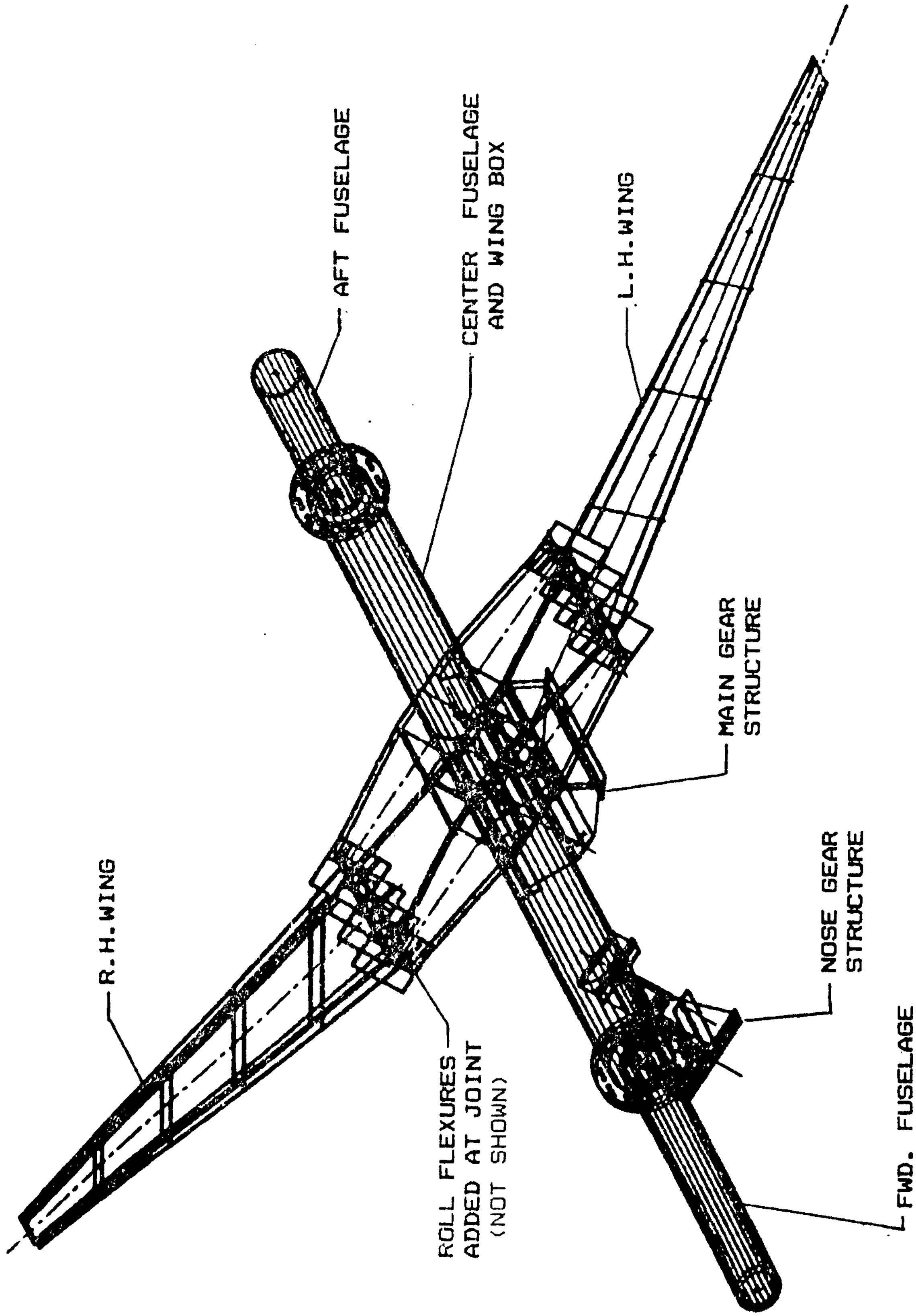
STRUCTURE:

An airplane contains many items which are not part of the structure. In a dynamic model, the weight of these parts can be used in the model structure making it possible to design a model structure relatively stronger than the airplane. The design details were selected in accord with this concept and with the objective of minimum fabrication cost.

DISCREPANCIES:

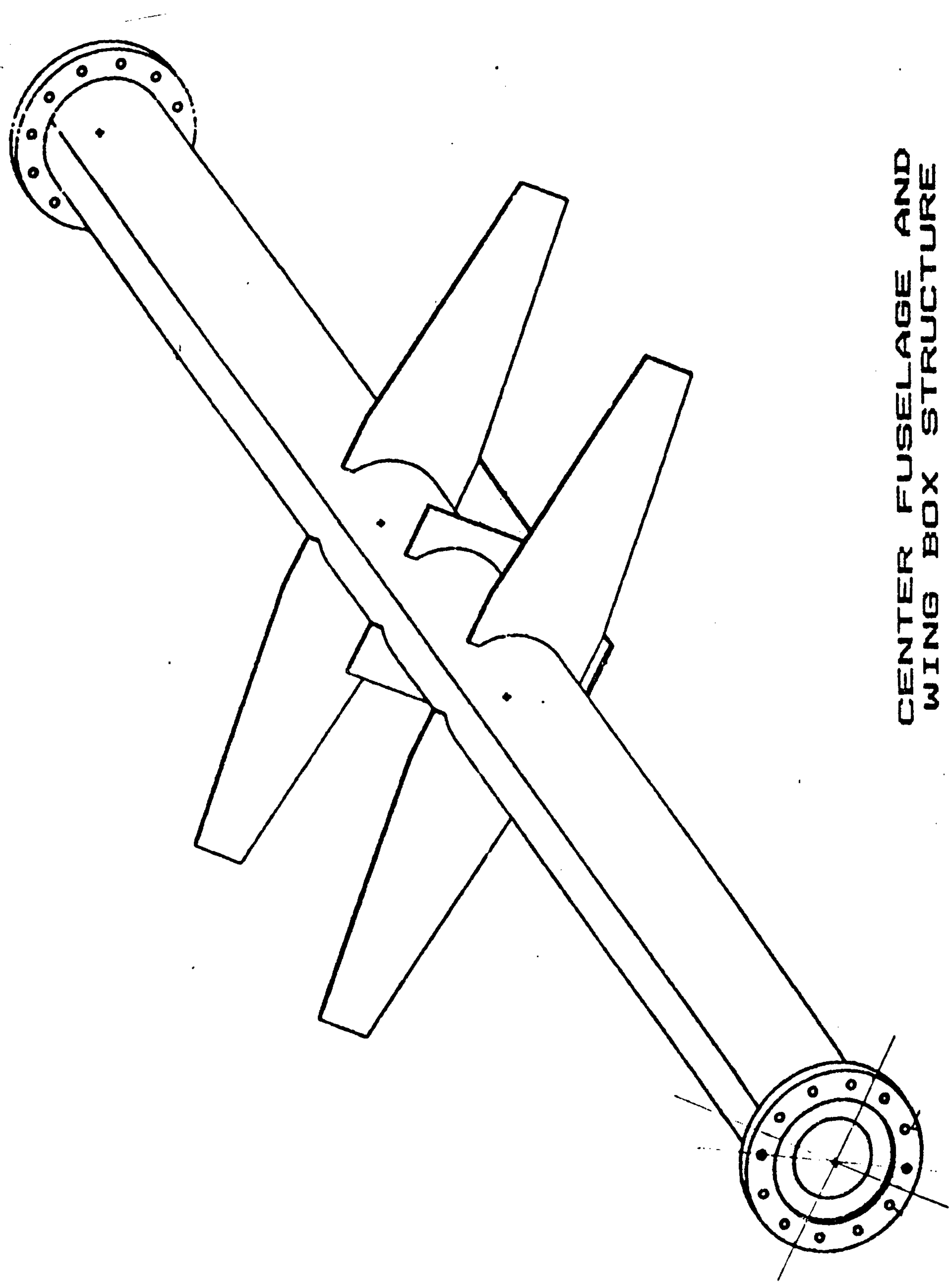
Past experience with building dynamic models (such as flutter models) has shown that the analytical math model may not represent some feature of the airplane. Also, some compromises and trade-offs are necessary in the model design. Therefore, it was believed necessary to fabricate a reduced scale model before attempting to fabricate a full scale model. A 1/8 scale model was fabricated using the computer design drawings for the full scale model. Some copies of the drawings are contained in the following pages. Major discrepancies with measured airplane frequencies and modes were attributed to fuselage roll inertia and wing root flexibility. These are discussed in appendix II.

F-16 – FULL SCALE



F-16 MODEL

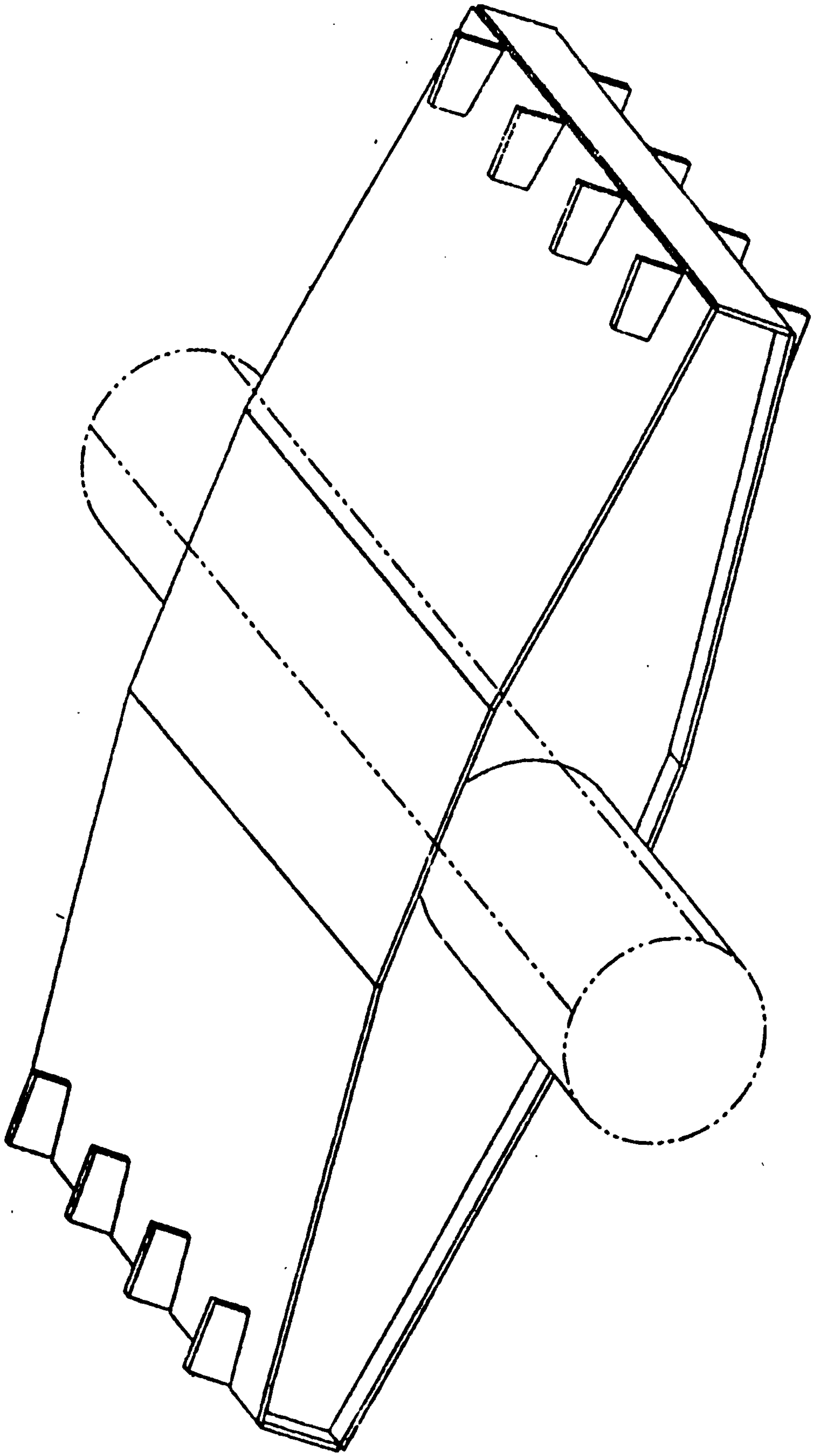
F-16 - FULL SCALE



CENTER FUSELAGE AND
WING BOX STRUCTURE

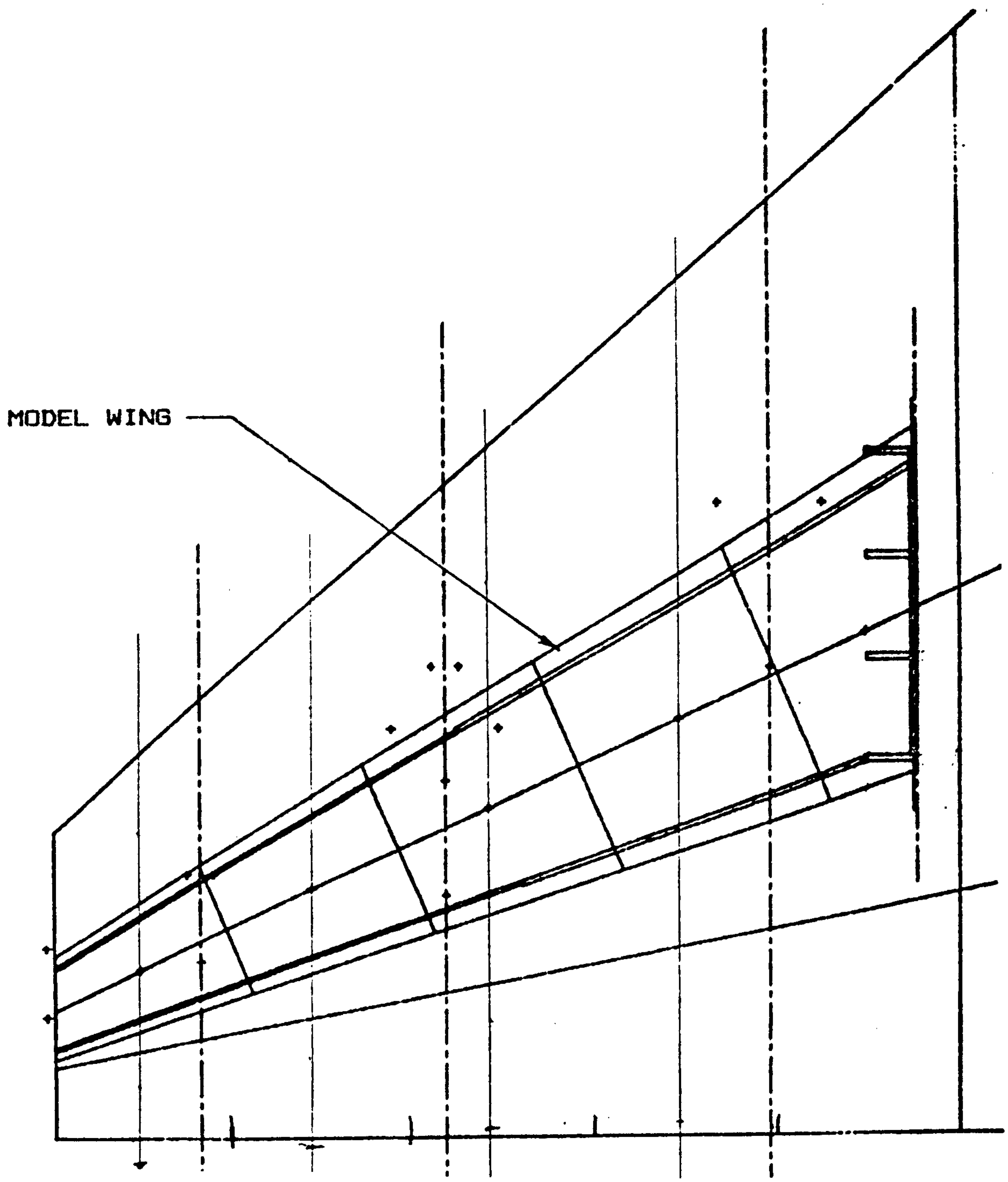
(COMMON FOR ALL MODELS)

F-16 - FULL SCALE



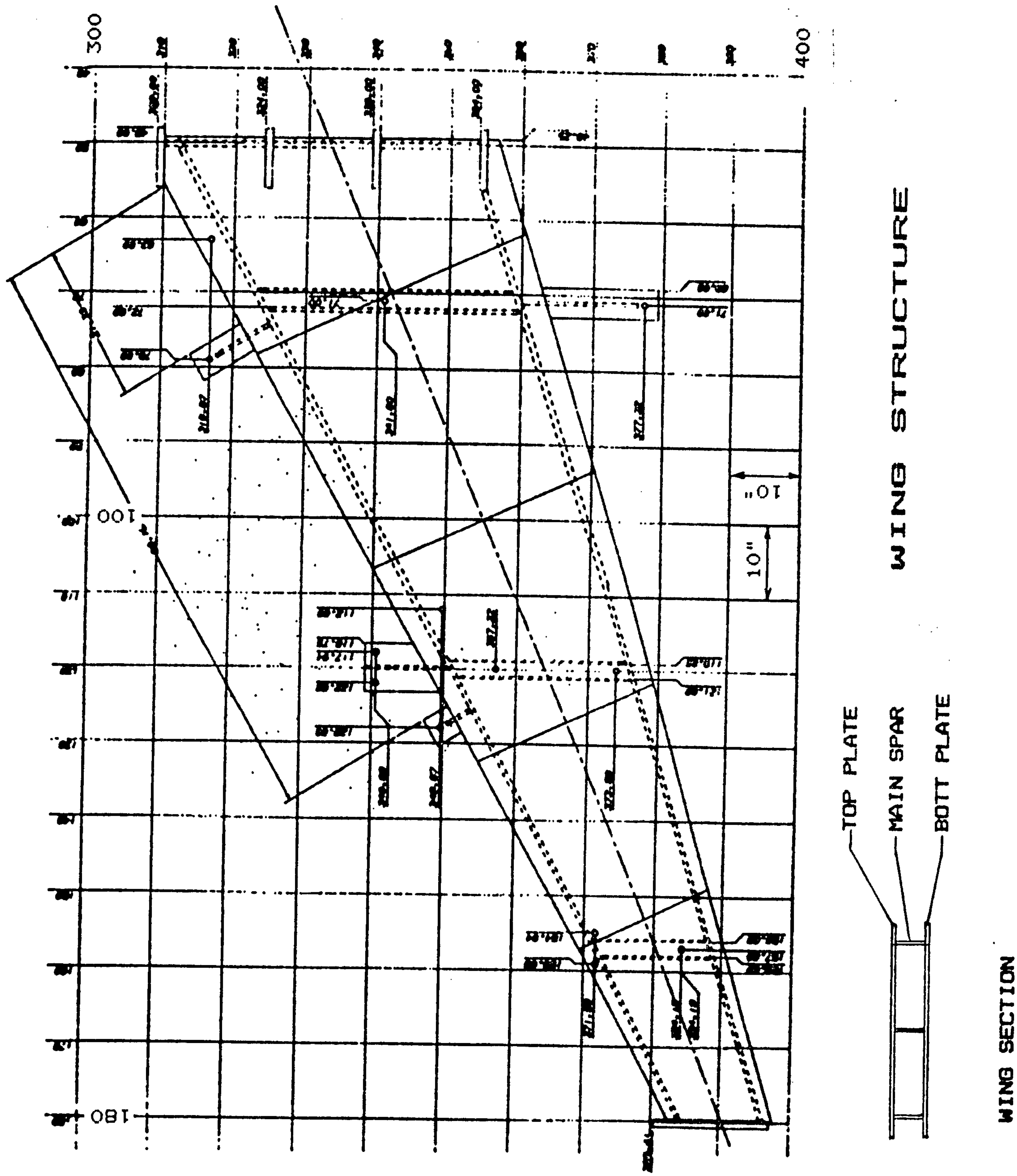
WING BOX ASSEMBLY
WELDED TO TUBE

F-16 - FULL SCALE



WING PLAN FORM

F-16 - FULL SCALE



F-16 - 1/8 SCALE

SCALE FACTORS:

Model Target = Airplane value * scale factor.

Property	Symbol	Units	Scale Factor
Length	L	in.	.125
Density	d	lb./in.^3	1.0
Velocity	V	ft./sec.	1.0
Weight/in.	W/L	lb./in.	1.56E-02
Weight	W	lb.	1.95E-03
Unbalance	S	lb.in.	2.44E-04
Inertia	I	lb.in^2	3.05E-05
Linear spring	k	lb./in.	.125
Bending spring	P/theta	lb./rad.	1.56E-02
Torsion spring	M/theta	in.lb./rad.	1.95E-03
Beam stiffness	EI;GJ	lb.in^2	2.44E-04
Frequency	f	Hertz	8.0
Acceleration	A	in./sec^2	8.0
Gravity	G	in./sec^2	.125
Static Defl.	z,s	in.	1.56E-02

NOTE: Since gravity is an acceleration, the model gravity should be 8 times full scale. However, gravity acceleration remains the same as full scale, and the static deflection of the model, caused by scaled masses, is only 1/8 of the linear scaled value for the full scale structure.

F-16 - 1/8 SCALE

FREQUENCIES AND MODES:

The modes reported here are limited to those considered to be significant for the AGILE program.

As described in earlier sections, the model was designed to simulate the F-16 airplane using mass and stiffness data obtained from various documents published by General Dynamics. Normally, if mass and stiffness distributions closely simulate the airplane, then the frequencies and modes will also correspond.

In the course of doing frequency and mode surveys of the model, it was found that the first A/S frequency was sensitive to the fuselage roll inertia. A bar was attached to the fuselage to increase the roll inertia. The target frequency was obtained when the roll inertia had been increased by 294 lb. in.^2.

The second symmetric wing bending was sensitive to the wing root flexibility. The root flexibility was varied experimentally until the target frequency was obtained. The value of the flexibility was measured experimentally and also calculated by analysis of the dimensions and geometry of the structure. The measured stiffness was 111,000 in.lb. per radian. The calculated value was 121,000 in.lb. per radian. The members were sized on the basis of the ability to carry the full bending moment of the wing. Torsion bars were used in consideration of space limitations and to minimize the effective mass in the mode involved.

AIRPLANE MEASURED MODES:

	Freq.- Hz	
Mode	Symmetric	Anti-symm.
First Wing Bend	4.8	5.9
Missile Pitch	7.0	8.3
Fuselage Bending	11.6	
Second Wing Bend	19.9	

1/8 SCALE MODEL MODES:

	Target Freq.- Hz		Meas. Freq.- Hz	
Mode	Symm.	A/S	Symm.	A/S
First Wing Bend	38.4	47.2	37	47
Missile Pitch	56.0	66.4	57	66
Fuselage Bending	92.8		105	
Second Wing Bend	159		159	

F-16 - 1/8 SCALE

WING TIP LAUNCHER AND MISSILE:

The cantilevered frequencies for the 1/8 scale model were tuned to match the scaled frequencies for the full scale measured frequencies supplied by G.D. as:

First - aft node.	11.0 Hz
Second - fwd node.	24.5 Hz

MASS PROPERTIES:

Data taken from G.D. report on the 1/4 scale flutter model.

Fuselage - with full fuel.
Wing - empty.
No pylons.
Tip launcher and AIM-9J.

Item	Airplane	Model - Target
Weight - lb.	21161	41.3
C.G. - inches	319	39.9
I;y,y - lb. in.^2	250 E06	7629
I;z,z - lb. in.^2	282 E06	8606
I;x,x - lb. in.^2	55.4 E06	1691

The design of the model fuselage did not attempt to meet any target for roll inertia. The G.D. report did not present data for the fuselage roll inertia so a value was determined by deducting other components from the total for the airplane. The values are given below:

FUSELAGE ROLL INERTIA:

	Airplane		Model - Target	
Item	Weight	I;x,x E-05	Weight	I;x,x
2 Horiz. tails	180	7.0	.35	21
Vert. tail	279	11.4	.54	35
2 Wings	1440	139.0	2.81	424
2 Launchers	114	38.3	.22	117
2 AIM	336	121.0	.66	369
Fuselage	18812	237.3	36.72	725
Airplane	21161	554.0	41.3	1691

F-16 - 1/8 SCALE

The fuselage roll radius of gyration is calculated as, R = 35.5. This radius completely circumscribes the main portion of the fuselage and therefore it appears that the value for roll inertia is too high. This apparent discrepancy has not been explained.

MODEL MASS PROPERTIES:

Data prepared from measurements made on the 1/8 scale model.

Fuselage - with full fuel.
Wing - empty.
No pylons.
Tip launcher and AIM-9J.

Item	1/8 Model	Deviation
Weight - lb.	50.99	23%
C.G. - inches	39.22	-.68in.
I;y,y - lb. in.^2	7168	-6%
I;z,z - lb. in.^2	8769	2%
I;x,x - lb. in.^2	1520	-10%

When it was decided to insert a wing root roll flexure, it was designed to carry the bending moment capacity of the wing and also make up for a large part of the deficiency in the fuselage roll inertia.

Mass properties of the root roll flexure are given in the table below:

Item	Flexure
Weight - lb.	9.60
I;y,y - lb. in.^2	192
I;z,z - lb. in.^2	462
I;x,x - lb. in.^2	270

Mass properties for the model without the wing root roll flexures are given below:

Item	1/8 Model	Deviation
Weight - lb.	41.39	0%
C.G. - inches	38.85	-1.05in.
I;y,y - lb. in.^2	6976	-9%
I;z,z - lb. in.^2	8307	-4%
I;x,x - lb. in.^2	1250	-26%

F-16 – 1/8 SCALE

STIFFNESS PROPERTIES:

Stiffness distribution data were obtained from General Dynamics. These were given in plots of EI and GJ vs. stations for the fuselage and the wing.

FUSELAGE:

The fuselage vertical EI curve was integrated to derive a vertical spring rate at the nose gear relative to the main landing gear location. A steel tube of constant EI was selected to provide this spring rate. The tube was also selected to obtain the approximate mass distribution for the fuselage.

WING SPAR:

The wing spar was designed to match the airplane EI and GJ at various stations. The stiffness plots were integrated for a torsion moment and a bending load at the tip to obtain target deflection values for comparison with measured model deflections. The results are presented in the tables below:

	Target values:		Measured values:			
	TORSION	BENDING	TORSION		BENDING	
Station	Theta/M E-05	Theta/P E-04	Theta/M E-05		Theta/P E-04	
			L.H.	R.H.	L.H.	R.H.
45	0.0	0.0	0.0	0.0	0.0	0.0
85	.97	1.50	.88	.85	1.51	1.54
114	2.58	3.21	2.64	3.61	3.49	3.52
140	5.90	5.53	5.90	6.20	6.14	6.17
167	16.60	9.06	15.10	15.10	9.88	9.76
180	30.00	10.10	27.6	27.6	11.40	11.30

ROOT ROLL FLEXURE:

According to the design data, the wing root roll stiffness was given as:

Airplane	388E06 in.lb./radian
1/8 Scale Model	758,000

F-16 - 1/8 SCALE

When the second wing bending freq. was measured at 228 Hz compared to a target of 159, an examination of the airplane GVT mode showed a significant slope at the wing root, indicating some rotation at that point. Therefore, it was thought that the effect of root flexibility should be investigated. As indicated earlier, the target frequency was obtained with:

Model wing root stiffness	111,000 in.lb./radian.
Airplane scaled value	56.8E06

This is only about 15% of the target value. If this truly represents a flexibility in the airplane, then there is large loss of stiffness in the attachment of the wing to the fuselage which is not accounted for in the data supplied. The following comments are offered for consideration:

1) The wing EI near the root is 3.0E09 lb.in.^2. At this constant EI, an active length of 53 inches is needed to produce an M/Theta value of 56.8E06 in.lb./rad. Such a panel of constant EI has a weight of about 296 lb. for the box plates alone. Fittings transmitting the bending moment from the wing to the fuselage are not uniformly stressed due to eccentric load paths and are less efficient in the storage of strain energy per pound. Therefore, more than 296 pounds would be needed in the members contributing to the root flexibility in order to transmit the full bending moment capacity of the wing root. Data used in the model design did not provide enough details to verify such a condition. For the specified root stiffness of 388E06 in.lb./rad. an active length of 7.7 inches is needed and the weight is 43 pounds. This appears to be more reasonable and indicates that the low stiffness value may only exist for small loads and deflections. Therefore, it may not be correct to evaluate the dynamic simulation by comparison with the second sym. frequency.

2) The bolted attachment of the F-16 wing could be non-linear depending on the preload in the bolts, assembly fit tolerances and other details.

3) If there is a non-linear characteristic that would be a significant factor, then the root roll flexure could be designed to represent this non-linear condition.

CONCLUSION

The physical properties of the 1/8 scale model indicate that this relatively simple structure is a satisfactory dynamic simulation of the F-16 airplane for use in conducting shake tests for the AGILE program.

DELTA DYNAMICS, INC.
Dayton, Ohio

FULL SCALE

COST ESTIMATE:

FABRICATION LABOR

These cost calculations are based on skilled labor rates at $40.00 per hour, including overhead.

WING:

Step	Operation	Manhours
1)	Shear And Machine Wing PLates	6
2)	Setup Plates On Flat Surface	1
3)	Weld Together	8
4)	Cut Spars	6
5)	Weld Spars to Bottom Plate	10
6)	Cut Ribs	2
7)	Weld Ribs	6
8)	Weld Top Plate	15
9)	Shear and Machine Root Blocks	5
10)	Weld Root Blocks	6
11)	Weld Pylon Blocks and Tip Rib	10
12)	Repair, Cleanup and Checkout	25
	Total	100

Cost = $4,000.00

The estimate received from T&R welding systems was $2,596.50 per wing or a total of $5,173 for two wings.

CENTER FUSELAGE:

Step	Operation	Manhours
1)	Flame Cut Main Fuselage Tube	2
2)	Setup Main Fuselage	2

FULL SCALE

3)	Fabricate Four Fuselage Rings	24
4)	Weld Main Fuselage Rings	6
5)	Shear And Flamecut Main Spars	6
6)	Shear And Flamecut Center Spars	2
7)	Shear and Drill Bending Plates	8
8)	Shear Side Plates	2
9)	Setup For Welding Carrythrough	8
10)	Weld Spars and Bottom Plate	6
11)	Weld Side Plates	5
12)	Weld Top And End Plates	4
13)	Weld Remaining Top and Bottom Plates	15
14)	Weld Wing Tie Bars	4
	Total	94

Cost = $3,760.00

The estimate from T&R Welding was $4,691 including $1,455 for a welding fixture.

REMAINING COMPONENTS:

1)	Forward Fuselage	10
2)	Aft Fuselage	8
3)	Main Gear Support Box	15
4)	Nose Gear Support Box	7
5)	Installation of Main Gear	40
6)	Installation of Nose Gear	20
7)	Assembly of Model	100
	Total	200

Cost = $8,000.00

FULL SCALE

COST SUMMARY

Item	Cost
Wing Material	$75,000
Fuselage Material	$25,000
Fabrication	$19,600
Root Flexure	$5,000
Supervision	$10,000
Engineering Modifications	$20,000
Total Cost	$154,600